



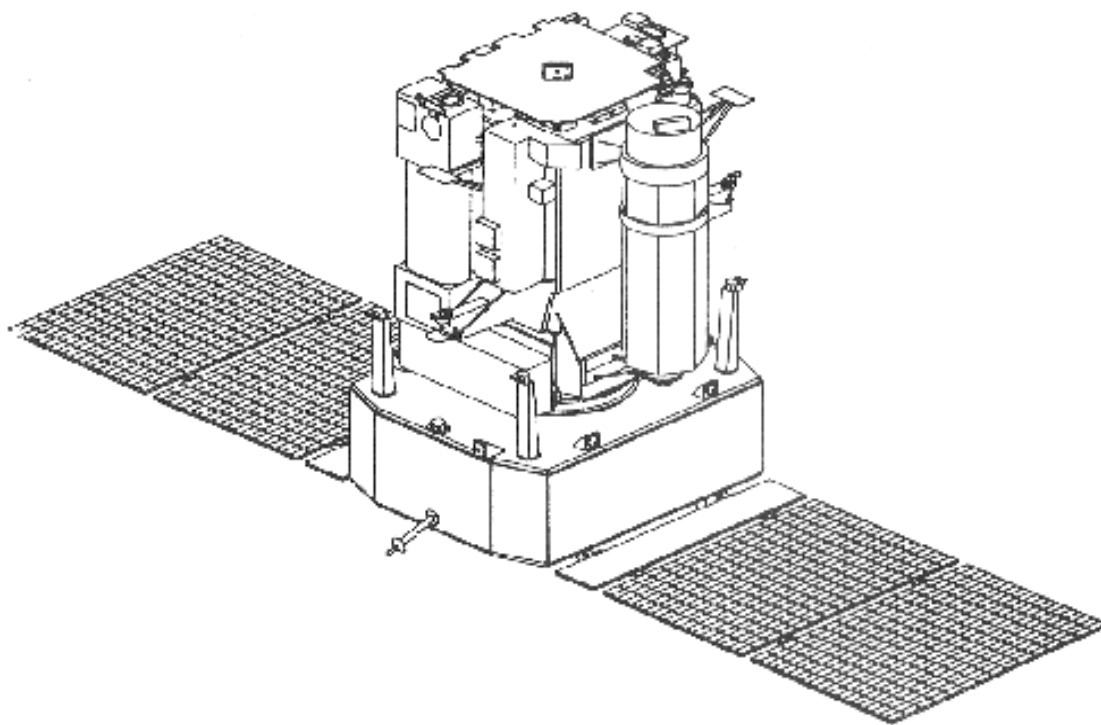
**Goddard Space Flight Center, Greenbelt**

# **SOHO**

## **ESR 24 Report**

### **(Dec 08, 2004)**

**Ref: SOHO/PRG/RP/602 2004 December 15**



**Prepared by:** B. SIMONIN (EADS ASTRIUM)  
T. V. OVERBEEK (ESA)

**Approved by:** T. V. OVERBEEK (ESA)

## Table of Contents

<b>1</b>	<b>Introduction .....</b>	<b>3</b>
<b>2</b>	<b>Reference documents .....</b>	<b>3</b>
<b>3</b>	<b>ESR-24 Description.....</b>	<b>3</b>
3.1	ESR-24 Triggering .....	3
3.2	Technical status prior to the anomaly .....	3
<b>4</b>	<b>ESR Recovery .....</b>	<b>4</b>
4.1	Attitude control.....	4
4.2	Nominal roll attitude recovery .....	4
4.3	Momentum Management.....	4
4.4	Back to Normal Mode .....	4
<b>5</b>	<b>Sequence of events .....</b>	<b>5</b>
<b>6</b>	<b>Rate adjustments .....</b>	<b>7</b>
<b>7</b>	<b>Roll maneuver and momentum management details .....</b>	<b>9</b>
7.1	Roll of -162.346 degrees .....	9
7.2	Momentum Management.....	9
7.2.1	First segment.....	9
7.2.2	Second segment .....	9
7.2.3	Third segment .....	9
<b>8</b>	<b>ESR-24 Analysis.....</b>	<b>12</b>
8.1	FSPAAD cleared.....	12
8.2	CSPAAD detection .....	13
8.3	Possible size of the particle .....	14
8.3.1	Particle sitting right at the top of the CSPAAD.....	14
8.3.2	Particle located 50 cm away from the CSPAAD sensitive area .....	14
8.4	CSPAAD response time .....	15
<b>9</b>	<b>Conclusion .....</b>	<b>17</b>

## **1 Introduction**

This document reports about the ESR #24 SOHO experienced on December 08 2004. The recovery phases are described, some of them in deeper details. A probable cause of the incident is also discussed.

## **2 Reference documents**

[RD - 1] SOHO Wheels behavior from April 21 to April 27, 2004 (ESRs 20-23)  
Ref: SOHO/PRG/TN/589 2004 May 17

## **3 ESR-24 Description**

### **3.1 ESR-24 Triggering**

On December 8, 2003 (DOY 343) at 21:59 UT, station D27 (Goldstone) lost contact with SOHO.

As Goldstone was not able to re-acquire, although all parameters were nominal on ground, a comms back-up at satellite level was suspected.

The telemetry was reacquired in low rate and, at 22:12, SOHO was confirmed being in ESR mode.

The transition to ESR mode was triggered by the CSPAAD (Coarse Sun Pointing Attitude Anomaly Detector). This detector kicks in when SOHO is off pointed from the sun by at least 25 degrees.

### **3.2 Technical status prior to the anomaly**

The last telemetry packets acquired in normal mode were examined and showed that the spacecraft performance and pointing were nominal when the ESR was triggered.

## **4 ESR Recovery**

The contingency script CS-06B (ESR Initial Operations) was conducted starting at 22:30 UT. As no 34m stations were available at that time and since no spacecraft emergency was declared (continuous contact with 26m DSN stations was provided for normal operations), SOHO stayed in low rate during the whole recovery process.

### **4.1 Attitude control**

The initial roll rate was very close to  $-0.1^\circ/\text{s}$ . No roll rate lowering was performed at that time. Three of them were performed later (00:30; 00:35 and 02:00 on DOY 344).

The upload of the gyroless patches started at 02:30 on DOY 344. One hour later, the wheels were switched on and spun up to 1800/-3600/1800 rpm.

Three roll rate adjusts ( $+20''/\text{s}$  each), one pitch rate adjust ( $+8''/\text{s}$ ) and eventually one roll rate adjust ( $-20''/\text{s}$ ) were commanded to stabilize yaw and pitch rates and allow transition to CRP at 04:44.

The spacecraft remained in ESR mode during 6 hours and 45 minutes.

45 minutes later, at 05:30, pitch and yaw profiles to restore FPSS offsets nominal values were completed.

It was then 12:30 AM local. A short meeting was held and it was decided to stop the activities for that day for people to get some rest. Activities were scheduled to start again at 08:30 AM local (13:30 UT) on DOY 344.

### **4.2 Nominal roll attitude recovery**

After the SSU switch on and mapping, FdF came up with a SOHO roll attitude value of  $+155.103^\circ$ .

To catch up the nominal roll attitude, a  $-162.346^\circ$  roll maneuver was needed.

No momentum management was required before the roll.

The roll maneuver began at 16:10 and lasted 25 minutes.

After this maneuver, the wheel speeds (1,2,3) were -1240, +3410, -2300 rpm.

### **4.3 Momentum Management**

When only considering wheel speeds, a momentum management was not mandatory after the roll maneuver. Indeed, based on after roll values, the expected wheel speeds on December 21 (next planned maneuver) would have been  $-1810, 3345, -2710$  rpm. However, with this speed set, Hx value turns out to be negative and, on December 21, very close to the  $-10$  Nms limit value.

To avoid any further problems, it has then been decided to perform a 3-segment momentum management that day.

Details of this maneuver are given in section 7. The wheel speeds after the maneuver were  $(-600, 3400, -1510)$  rpm and this set leads to acceptable wheel speed values on December 21  $(-1270, 3480, -2010)$  as well as a very comfortable  $+0.75$  Nms for Hx.

### **4.4 Back to Normal Mode**

SOHO was back in Normal Mode on December 9 at 22:42.

## 5 Sequence of events

Time (UT)	Activities
	<b>8-DECEMBER (DOY 343)</b>
21:59	Loss of telemetry during D27 pass. Comms Backup suspected
22:12	Telemetry confirmed <b>SOHO</b> in ESR
22:30	<b>Started CS-06B ESR script</b>
22:30 - 23:20	Script CS-06B conducted. Not performed: <ul style="list-style-type: none"> <li>- Command to switch to medium rate (D27 is a 26m station)</li> <li>- OBT adjustment (OBT was correct)</li> </ul>
23:23	<b>Switch to CS-18 script: ground based roll control</b>
23:24	Roll rate determination. Roll rate was close to $-0.1$ deg/sec; it was decided not to perform any roll control burns at that time
23:25	<b>Back to CS-06B script from step 6</b>
23:25	Step 6 (ESR data collection) performed
	<b>9-DECEMBER (DOY 344)</b>
00:00	Step 7 (Yaw/Pitch braking) skipped
00:10 - 01:36	Step 8 (Experiment in safe mode) conducted
00:27	Roll control command loaded. Fires @ 00:30
00:32	Roll control command loaded. Fires @ 00:35
01:37	<b>Script CS-06B completed. Resuming script CS-06A</b>
01:38	FPSS-A ON
01:50	ESA gave authorization to proceed with recovery
01:56	Roll control command loaded. Fires @ 02:00
02:00 - 02:14	Step 5 (switch from ACU-B to ACU-A) conducted
02:15	<b>CSPAAD criterion disabled</b>
02:16 - 02:27	Step 6 (CAE A ON) conducted
02:28 - 04:05	Step 7 (gyroless patches upload) conducted
03:48 - 04:08	Wheels spin up; final speeds (+1800/--3600/+1800) rpm
04:10 – 04:50	Step 8: transition to CRP
04:12	Roll adjust [20"/s, 0, 0]
04:20	Roll adjust [20"/s, 0, 0]
04:28	Roll adjust [20"/s, 0, 0]
04:34	Pitch adjust [0, 8"/s, 0]
04:36	Roll adjust [-20"/s, 0, 0]
04:44	<b>Spacecraft in CRP mode</b>
04:49	Command "Close LV-B" sent. Executed @ 05:05
04:51	Step 9 (Cat bed heaters ON) skipped. Postponed to the day after (local time)

<b>Time (UT)</b>	<b>Activities</b>
04:55	Step 10 (SSU A ON) conducted
05:00 – 05:30	Step 11: profiles in CRP
05:14	Pitch profile completed (Pitch offset = -198 arcsec)
05:26	Yaw profile completed (Yaw offset = 0 arcsec)
05:30	End of activities that night (12:30 AM local time)
<b>13:31</b>	<b><i>Resume script CS-06A</i></b>
13:31 – 16:40	Step 12: determine absolute roll attitude and step 13: nominal roll attitude recovery
14:45	FDF: roll attitude +155.103 deg No momentum management needed before the roll maneuver
16:10	Roll profile in CRP (-162.346 deg)
16:15	Execute step 9 (Cat bed heaters ON)
16:34	Roll completed
19:09	Transition to RMW in order to perform a Momentum Management
20:00	Segment 1 Thruster 5 (roll). Target speeds (-515/3385/-1580) rpm
20:25	Segment 2 Thruster 3 (yaw). Target speeds (-580/3365/-1495) rpm
20:35	Segment 3 Thruster 2 (pitch). Target speeds (-600/3400/-1510) rpm
20:50 - 21:59	Step 15: Comms backup recovery conducted
22:00 - 22:29	Step 16 (instrument checkout) and 17 (transition to RMW) conducted
22:30	Start maneuver end script (transition to NM)
<b>22:42</b>	<b>Spacecraft in Normal mode</b>

## 6 Rate adjustments

The rate adjustments are directly translated into wheel speed modifications according to the following equations [RD - 1]:

- a  $+X$  arcsec/sec roll rate modification leads approximately to a  $-X$  rpm change on wheel 1 and wheel 3 speeds.
- a  $+X$  arcsec/sec pitch rate modification leads approximately to a  $-0.9X$  rpm change on wheel 1 and wheel 3 speeds and a  $+1.8X$  rpm change on wheel 2 speed.

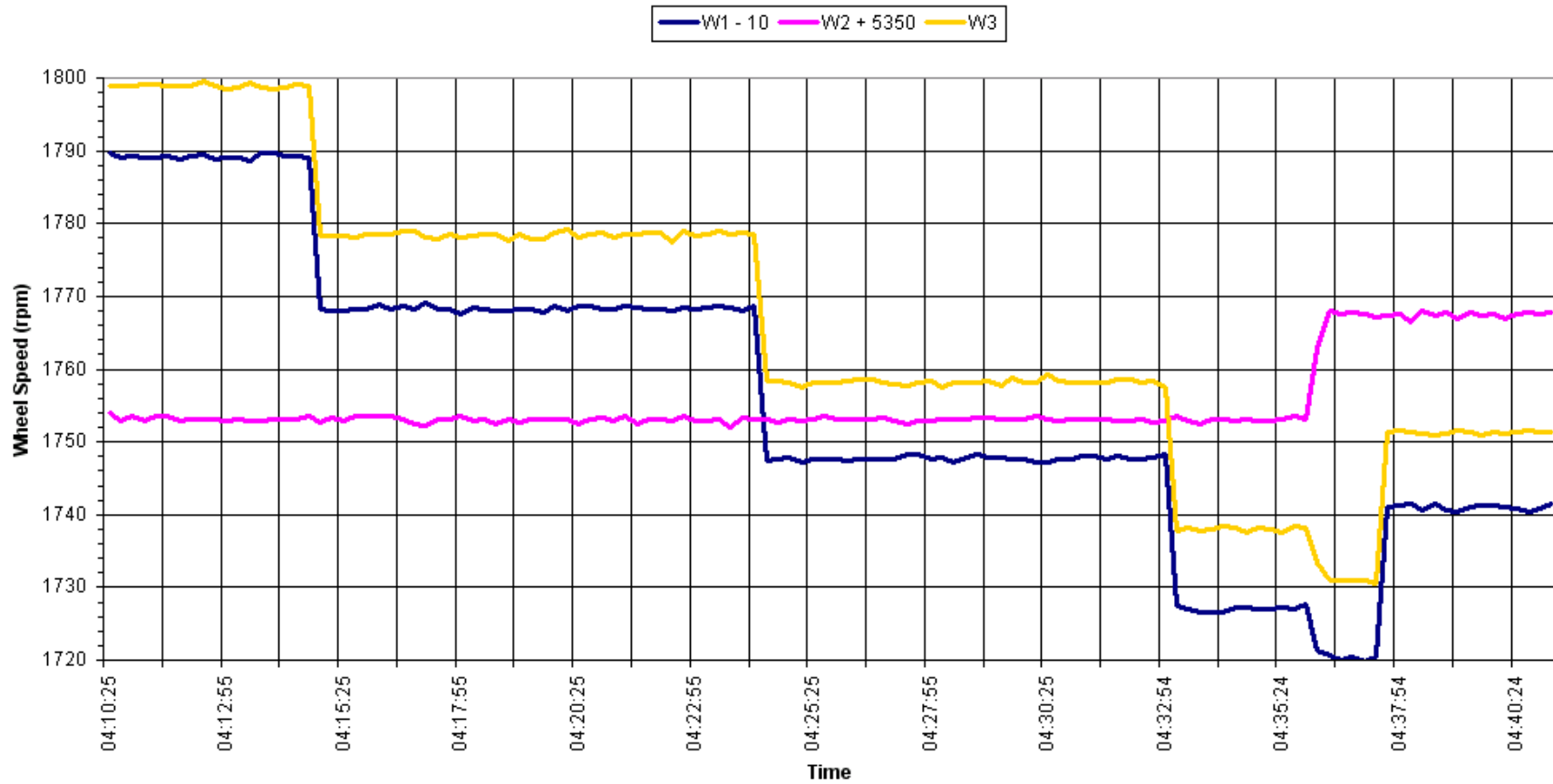
There were a total of 5 rates adjustments performed during ESR 24 between 04:10 and 04:40 on DOY 344.

The table hereafter gives the speed changes for the different adjustments.

The plot on the next page shows the wheel speeds changes during the adjustments.

Type of adjustment	Delta W1 (rpm)	Delta W2 (rpm)	Delta W3 (rpm)
Roll (20"/s,0,0)	-20.5	0	-20.14
Roll (20"/s,0,0)	-20.5	0	-20.14
Roll (20"/s,0,0)	-20.5	0	-20.14
Pitch (0,8"/s,0)	-7.19	+14.44	-7.07
Roll (-20"/s,0,0)	+20.5	0	+20.14

### ESR 24 Adjustments (DOY 344)





## 7 Roll maneuver and momentum management details

### 7.1 Roll of -162.346 degrees

Start time (UTC)	Angle (degrees)	Profile Duration
2004.343.16:10	-162.346	25 minutes (+15 minutes for WS stabilization)

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial (1)	1727	-3580	1723
Final (2)	-1240	3410	-2300
<i>Delta (2-1)</i>	-2967	+6990	-4023

### 7.2 Momentum Management

#### 7.2.1 First segment

Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration
2004.344.20:00	5A (R)	31	100.9	3.128	35	17min 30"

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial (1)	-1240	3410	-2300
Final (2)	-515	3385	-1580
<i>Delta (2-1)</i>	+725	-25	+720

#### 7.2.2 Second segment

Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration
2004.344.20:25	3A (Y)	4	213.0	0.852	35	1min 45"

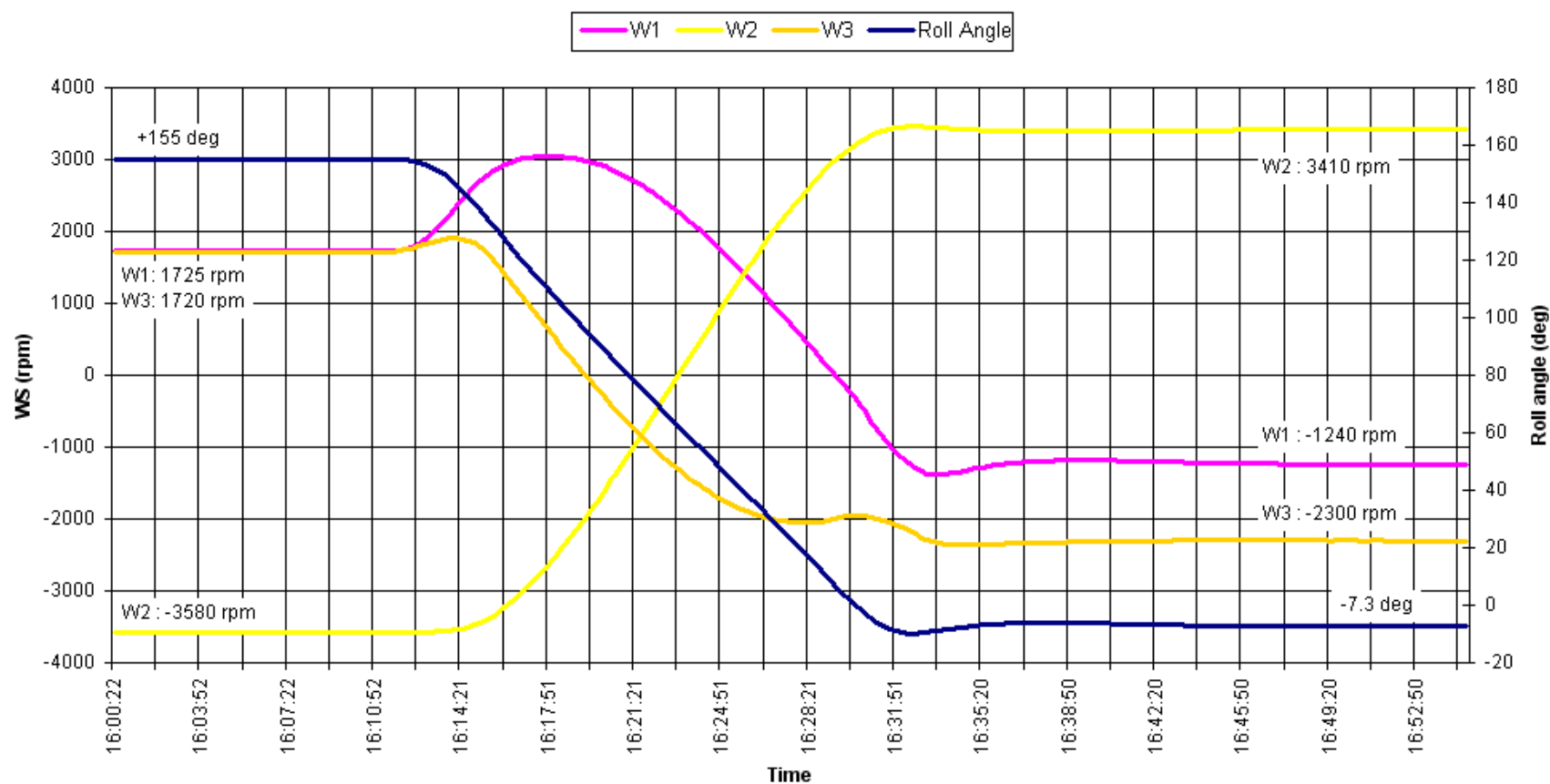
Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial (1)	-515	3385	-1580
Final (2)	-580	3365	-1495
<i>Delta (2-1)</i>	-65	-20	+85

#### 7.2.3 Third segment

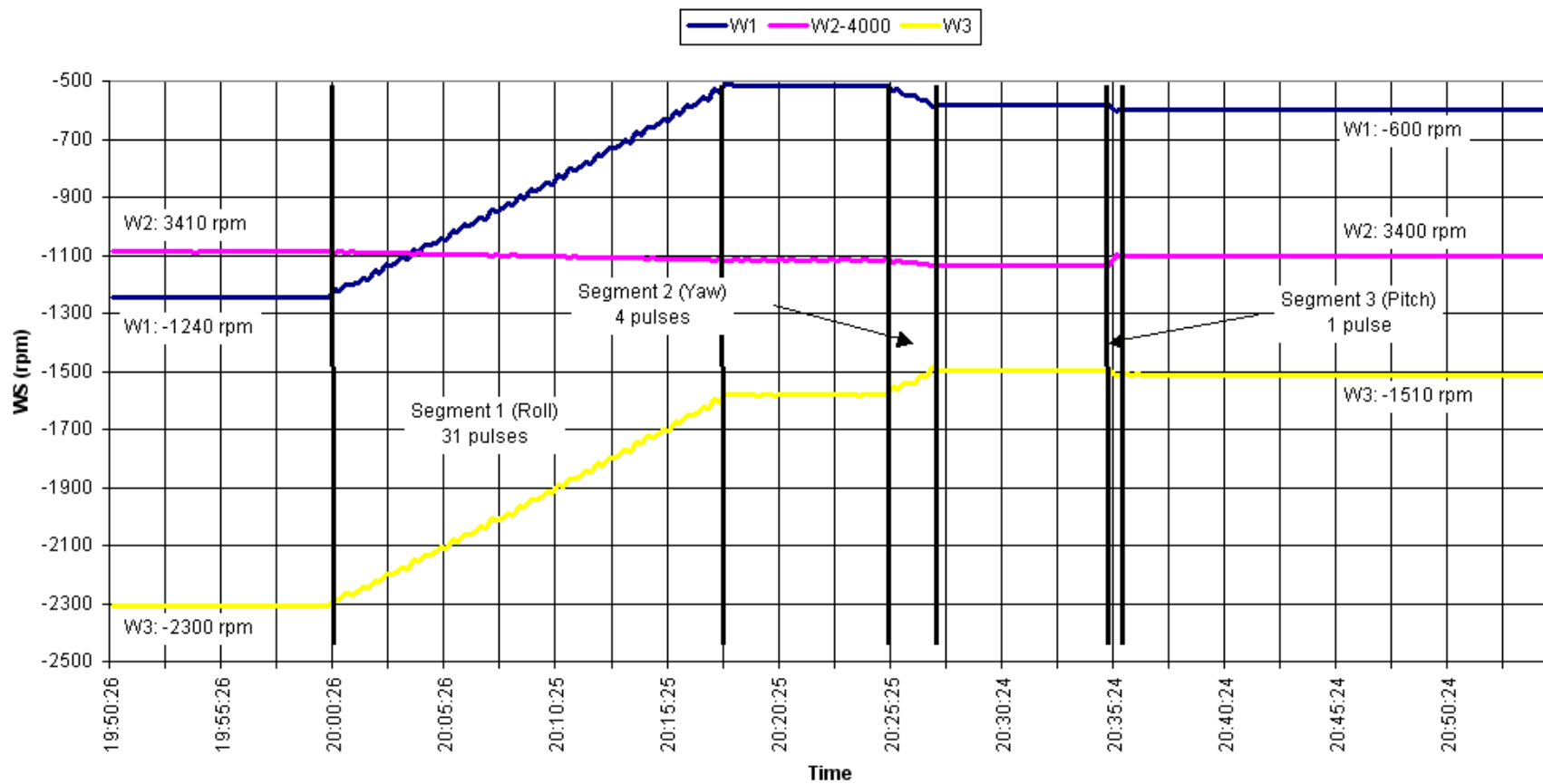
Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration
2004.344.20:35	2A (P)	1	103.8	0.104	60	1 min

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial (1)	-580	3365	-1495
Final (2)	-600	3400	-1510
<i>Delta (2-1)</i>	-20	+35	-15

# ESR 24 Roll Maneuver



# ESR 24 Momentum Management



## 8 ESR-24 Analysis

The CSPAAD kicks in when the spacecraft is sun off pointed by more than 25 deg. This was not the case when CSPAAD triggered on DOY 343 which means that SOHO fell back in ESR on a false detection.

It is the first time the CSPAAD triggers erroneously. The CSPAAD conditioning circuit is exactly the same as for the FSPAAD. When the FSPAAD was used (ie till April 2004), it sometimes triggered without any particular reason.

The electronic circuits processing the CSPAAD/FSPAAD signals in the FDE house a LM 139 comparator, known for its susceptibility to SEUs.

If the CSPAAD had triggered without the history we have on FSPAAD, SEU would probably have been considered as the cause of this false detection.

Some other elements tend to lead to another possible cause.

### 8.1 FSPAAD cleared

After ESR 20-23 in April 2004, the FSPAAD capability to trigger an ESR was disabled. Indeed, even with the presence of a 16-second filter to avoid detection on a single glitch, the FSPAAD systematically triggers when SOHO is perfectly pointed.

However, during the ESR 20-23 recoveries, it was pointed out that, as soon as SOHO is slightly off pointed, the FSPAAD does not trigger anymore.

The most probable cause so far for this systematic triggering while perfectly pointed is the presence, somewhere in the FSPAAD vicinity, of a particle large enough to occult the sun.

To try to determine the shape of this object "seen" by the FSPAAD in its field of view, a scanning around the nominal position would be very efficient. This test was supposed to be performed sometime between late 2004 and mid 2005 when the impact on scientific observations would be minimal.

In the meantime, the detection is cleared every week (every Thursday) to verify that no change occurs.

On Thursday December 2, 2004, 6 days prior to ESR 24, FSPAAD still returned a "detected" status.

After SOHO came back to its nominal pointing during ESR 24 recovery, it was noticed that the FSPAAD no longer triggered, which means the particle supposed to sit in the FSPAAD vicinity has gone.

A week has passed and the FSPAAD has still not triggered.

The "particle" explanation then makes more and more sense.

## 8.2 CSPAAD detection

CSPAAD and FSPAAD sit side by side on the same base as shown in the picture hereafter.

CSPAAD is the detector with the widest aperture (25 deg half cone) on the right of the picture while FSPAAD is the one with the smallest aperture (5 deg half cone).



SOHO AADs

As FSPAAD is disabled, CSPAAD remains the only independent failure detection channel. It has then been reactivated after the recovery and has not triggered so far. For the moment, both FSPAAD and CSPAAD seem to work properly.

Taking these elements into account, the most probable cause found for ESR 24 is:

A particle occulted the FSPAAD field of view. This particle moved away from FSPAAD for an unknown reason and occulted on its way the CSPAAD, which triggered ESR 24.

### **8.3 Possible size of the particle**

The x (sun line) and y ("east-west") coordinates of SOHO on December 08<sup>th</sup> were respectively 1244797 km and 315677 km.

Considering an earth-sun distance of  $1.5 \times 10^8$  km, a simple geometric calculation gives the SOHO – Sun distance (l) on December 05:

$$l = \sqrt{(315677)^2 + (1.5 \times 10^8 - 1244797)^2}$$

$$l = 148755538 \text{ km.}$$

The pinhole in front of the sensitive area at the bottom of the CSPAAD has an aperture diameter of 0.9 mm and its radius r is 0.45 mm. The sun diameter is  $1.4 \times 10^6$  km and its radius s is 700000 km.

If a particle sits at a distance d of the aperture, another geometric calculation gives the minimum p value of the particle radius that could occult the CSPAAD field of view.

p is given by the formula:

$$p = \{r * [(l * r) / (s - r) + d]\} / [(l * r) / (s - r)]$$

#### **8.3.1 Particle sitting right at the top of the CSPAAD**

In that case,  $d = 44.5$  mm and then  $p = 0.659$  mm

A particle as small as 1.32 mm in diameter sitting right at the top of the CSPAAD completely occults its field of view.

#### **8.3.2 Particle located 50 cm away from the CSPAAD sensitive area**

With  $d = 50$  cm, it comes  $p = 2.803$  mm

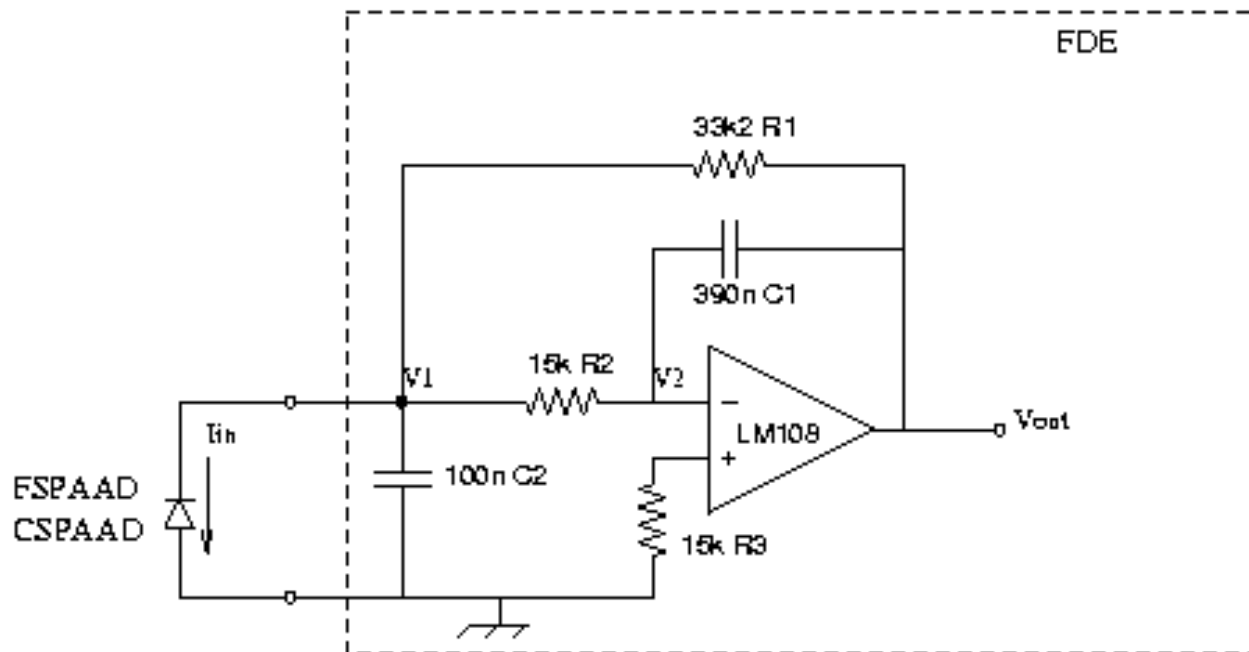
A particle of 5.61 mm in diameter at a distance of 50 cm from the CSPAAD sensitive area completely occults its field of view.

These two examples clearly show that a very small particle can totally occult the CSPAAD detector.

The minimum diameter of this particle depends on the relative position of the particle from the CSPAAD sensitive area.

## 8.4 CSPAAD response time

CSPAAD and FSPAAD are conditioned in the FDE by two identical electronic circuits. A drawing of these circuits is given hereafter.



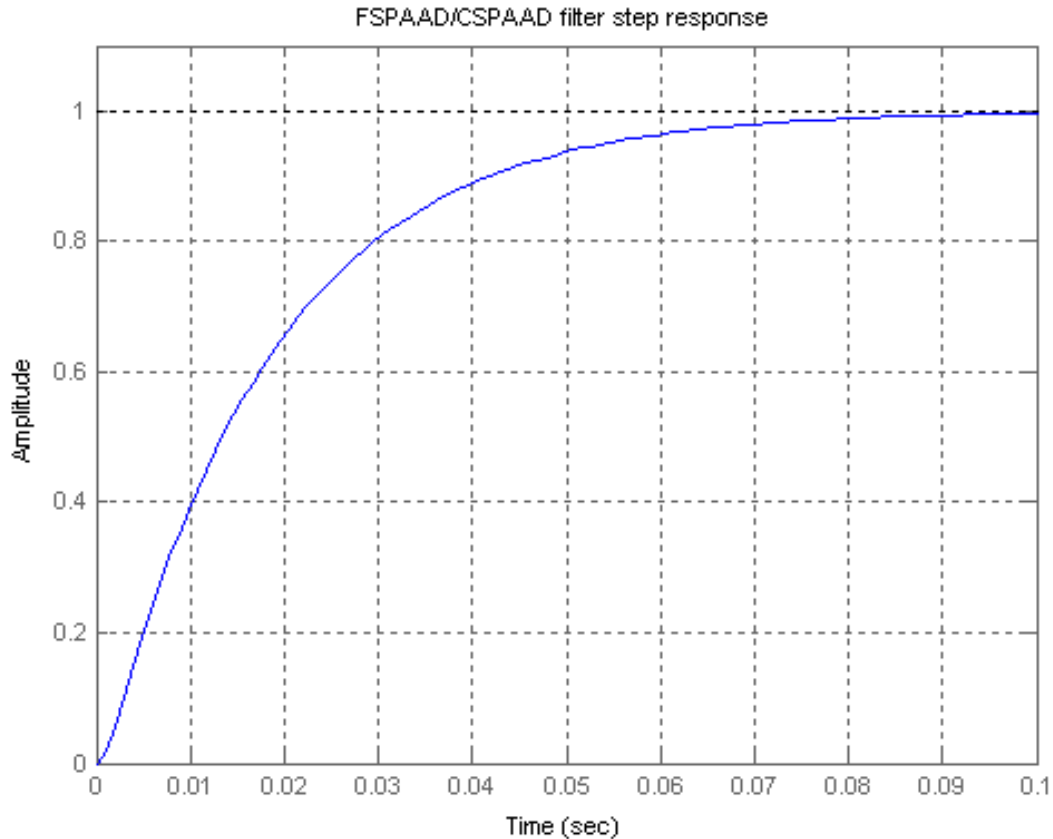
Considering zero value for the voltage at V2 point, the transfer function of this circuit is given by the formula:

$$V_{out}/I = R1 * [1/(1 + s*C1*(R1+R2) + s*s*C1*C2*R1*R2)]$$

where  $s = j \omega$

with  $\omega = 2*PI*f$  (where  $f$  is the frequency) and  $j$  known as  $j*j = -1$

Hereafter is the plot of a step response applied to this transfer function.



By analyzing this plot, it can be seen that the circuit will trigger if the signal is present for more than about 45 ms (90% rise time).

In other words, there is practically no filtering on this circuit and as soon as the CSPAAD (as well as the FSPAAD) is occulted, it triggers.

Coming back to the "particle" theory, it means that if a particle flies over one of these detectors, even for a short period of time, the probability it will lead to an ESR is close to 1.

This perfectly fits with the assumption of a particle taken away for any reason from the FSPAAD detector and triggering ESR 24 while flying away from SOHO.



## **9 Conclusion**

The ESR 24 was triggered on a CSPAAD false detection.

The recovery was conducted without any particular problems and without any spacecraft emergency declaration.

The FSPAAD seems to be cleared now and the CSPAAD was reactivated two days after detection.

The most probable cause of the detection is a particle crossing the CSPAAD field of view and coming from the FSPAAD.

The FSPAAD remains inhibited. If, after a sufficiently long period of time (criterion TBD), the FSPAAD is still cleared, its reactivation could be considered.

## Distribution list

<b><u>at GSFC</u></b>	H. BENEFIELD C. GINTHER N. PISTON S. THORPE	R. DUTILLY J. GURMAN B. SAPPER T.V. OVERBEEK	B. FLECK R. MAHMOT H. SCHWEITZER B. SIMONIN
<b><u>at ESTEC</u></b>	J. LOUET	P. RUMLER	F. TESTON
<b><u>EADS ASTRIUM</u></b> <u>Toulouse</u>	P. AYACHE  G. GUILLERM D. LEBRETON	M. CHALOUPIY  M. HORBLIN P. LELONG	B. DEHERLY  M. JANVIER
<b><u>EADS ASTRIUM</u></b> <u>Stevenage</u>	A. HOLT		
<b><u>EADS ASTRIUM</u></b> <u>Portsmouth</u>	B. EDWARDS		

## Contacts:

B. SIMONIN	tel: 1 301 286 4880
	e-mail: bsimonin@hst.nasa.gov
T. VAN OVERBEEK	tel: 1 301 286 5963
	e-mail: tvoverbeek@hst.nasa.gov